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HUMANOID ROBOTS IN HIGHER EDUCATION: AN EXPLORATORY STUDY ON APPLYING THE NAO ROBOT AS AN EDUCATIONAL TECHNOLOGY IN BUSINESS STUDIES IN HYBRID SETTINGS

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Abstract

Current research on applying humanoid robots in education as part of the field of robot assisted learning provides some promising evidence about enhancing learning experiences of students through human-robot interaction. Currently available humanoid robots provide a multimodal interface which uses touch, speech, gestures and eye gaze for interaction which is similar to human experiences of interaction in the physical world. However, applications of humanoid robots in higher education are still scarce and little is known about interactions and perceptions of students in relation to humanoid robots as educational technologies. This paper presents the design of humanoid robot assisted learning scenario and the results of an exploratory study with 27 undergraduate students who participated in the robot experiment with the humanoid robot NAO in hybrid settings. The study presented in this paper explored how students perceived the NAO robot as an educational technology and how they assessed the interaction with the robot as a facilitator in small student teams. The results of the study show that students positively assessed the NAO as an educational technology and perceived NAO as a friendly, likeable, funny, trustworthy and motivating anthropomorphic agent. The results also indicate that humanoid robots like NAO may be helpful for enhancing both engagement and learning outcomes of students in higher education. The paper ends with suggestions for further use of humanoid robots in higher education and recommendations for further research in humanoid robot assisted learning.

Keywords: humanoid robots, educational robots, (HRI) human robot interaction, (RAL) robot-assisted learning, (RIE) Robotics in Education, (RSCL) robot supported collaborative learning, (TEL) technology-enhanced learning.

1 INTRODUCTION

Educational robots have been used as an innovative educational technology for quite some time now, at least since the beginning of the 1960s and the introduction of the Logo turtles by Seymour Papert, which have been considered as the first educational robots [1]. Educational robots have been typically used to support computational and engineering thinking, the development of logical thinking skills and of problem solving capabilities, mainly in schools [2], [3]. The predominant practice has been robotics classes and coding workshops in schools designed to provide opportunities for developing computational skills for school children [2]. Humanoid robots have only recently entered the field of Robot Assisted Learning (RAL), Robotics in Education (RIE) and Robot Supported Collaborative Learning (RSCL). Currently available humanoid robots, such as the NAO robot, provide a multimodal interface which uses touch, speech, gestures and eye gaze for interaction, which is meant to be similar to human interaction in the physical world. However, the practice of introducing humanoid robots to support learning of students in higher education is still at its initial stage and student-robot interactions have just started to be designed and explored. Some of the current applications of humanoid robots in higher education, such as the NAO robot, have included using NAO as a teaching assistant for vocabulary learning of university students in context of robot assisted language learning (RALL) [4], using NAO to create innovative therapy sessions for people with physical disabilities by undergraduate engineering students in collaboration with a rehabilitation institute [5], and using NAO to facilitate collaborative activities in small groups [6].

The NAO robot is one of the most popular humanoid robots applied in education. The NAO robot was designed by the Aldebaran Robotics company in 2008 in France and taken over by SoftBank Robotics in 2012 [4]. It is an autonomous, programmable humanoid robot with 25 degrees of freedom, speech recognition, four directional microphones and speakers for sound localisation and multilingual text-to-speech synthesis, four in-built cameras for facial and shape recognition, seven touch sensors, and the ability to interact in 20 languages [5]. NAO is 58 centimetres tall, weighs 5.6 kilograms and can perform simple human movements, such as walking forwards and backwards, sitting down and standing up and waving [4], [5]. NAO robots have been used to support therapies, e. g. for children with autism, classroom activities, e. g. in mathematics, instruction and communication in a public setting such as hospitals, museums and schools as well as competitions such as Robocup [5], [7], [8].

Research related to the application of the NAO in higher education has shown that students (age M = 20 years) enjoyed interacting with the NAO robot, like its abilities and tend to think that NAO supports their learning [4]. Other studies, such as the study by [6], in which the NAO robot facilitated a small group activity of students in higher education, have shown that even older students (age M = 28 years) perceived NAO as a pleasant, friendly and interesting facilitator, even though the robot did not directly respond to their verbal communication. The study by [6] has also shown that students preferred an interaction with the robot compared to an interaction with a tablet, and even felt more comfortable interacting with the robot compared to interacting with a human instructor or a tablet.

2 METHODOLOGY

2.1 Aims and design of the study

This study aimed to explore how university students perceived the NAO robot as an educational technology and the interaction with the robot as a facilitator in small student teams.

The study was conducted at Berlin University of Applied Sciences (Germany) with students in the bachelor program Digital Business (B. Sc.) in Department I Economics and Social Sciences. The participants were undergraduate students in the course on Agile Project Management (APM) in the third semester of their studies. One of the classes in the APM course was designed as a hybrid event, with students participating on the campus and online via the web conferencing system Zoom. Altogether 15 students participated in the experiment on the campus, and 25 students participated online via Zoom. The number of students participating on the campus was limited to 15 due to the COVID-19 pandemic regulations. Students on the campus participated in two robot-led sessions, while students participating via Zoom observed the experiment. Both groups of students participated in the online survey during the class. Participation in the study was voluntary. Students who participated on the campus received bonus points which added to their final grade in the APM course. From the cohort of students participating in the experiment, 27 responded to the online survey.

The study encompassed a number of stages. First, the students signed the participant list and the consent for the video-recording of the experiment. Second, the lecturer in the APM course (the first author of this paper) explained the procedure to the students with specific instructions to those on the campus and to those participating online. Third, the programmer of the NAO robot (the second author of this paper) gave a short introduction about the NAO robot. After the introduction part, the first small group of five students participated in the first daily scrum in English. Since the NAO robot became unresponsive towards the end of this first session, probably due to the noisy environment with 15 students in the classroom, the robot had to be reset and this time was used to participate in the online survey. After resetting the robot and finishing the online survey, the second daily scrum in German was conducted with the second group of five students.

The robot-led sessions were thematically related to the curriculum of the Agile Project Management course and were designed as daily scrum events, one in English and one in German. Daily scrums (or daily stand-ups) are 15-minute events held by teams working according to the agile framework Scrum. Agile teams are typically coached by the Scrum Master, and daily stand-ups are used as an opportunity to coach the agile team [9]. In the robot experiment described here, the NAO robot was programmed to facilitate the daily scrum as Scrum Master in order to coach the team on how to keep a daily scrum.

2.2 Programming of the NAO robot

The NAO robot can be programmed using the Choregraphe NAO software, which is a graphical environment allowing to design robot interactions without coding, and several programming languages such as Python, C++, MATLAB, JAVA and LabVIEW. The NAO robot provides a C++ API called NaoQi, which enables using NAO as an autonomous agent or as a remotely controlled machine [10]. The NAO robot used in the study described in this paper was NAO Power V6 Educator Pack. It was programmed for the study entirely by one student (the second author of this paper) using Choregraphe (Version 2.8.6) for the logical connection of the individual exercise points and Python for each Choregraphe-Box, by adding the Python code to Choregraphe.

When programming NAO several considerations had to be made. First, when designing a future scenario with the NAO robot, it was necessary to define the aims of the study, to provide an outline of the entire process, define the content to be conveyed to students and the number of participants participating in the exercise as well as expected results. Therefore, in the first step a concept of the daily scrum exercise was developed outlining the key element. The typical format of a daily scrum event with three standard questions asked during the daily scrum, i. e. What did you do yesterday? What will you do today? Are there any impediments in your way?, was used as a template to design the exercise. The design of the exercise starts with the NAO robot explaining the daily scrum exercise to a small group of participants and collecting information about how many participants will take part in by asking the question “How many students will participate in this exercise?” Therefore, the programming of the NAO robot included the explanation of the exercise, the query about the number of participants and lastly the execution of the actual exercise in the form of a daily scrum.

Further considerations included the settings of the study and the interaction with the students. In this study, the setting was defined to be a laboratory room or a seminar room at the university, with participants including the NAO, the students (as daily scrum participants and as observers) and lecturers. The daily scrum was to be designed to be as interactive as possible, at the same time taking into consideration that noisy conditions in human-computer interaction can be challenging for speech recognition [10]. The NAO robot has two microphones placed around the head and only a basic noise reduction technique is applied to improve the quality of processed sounds [10]. Therefore, when designing the study, not only speech recognition but also NAO’s tactile sensors, such as foot bumpers located at the tip of each foot and touch on the top of the head, were used to facilitate interaction with the students. The touch of the bumpers was used after selecting the language and greeting the participants. The touch on the head was used when NAO waited to start explaining the exercise.

The sequence of the daily scrum scenario programmed for the NAO robot is shown in the diagram below (Fig. 1).

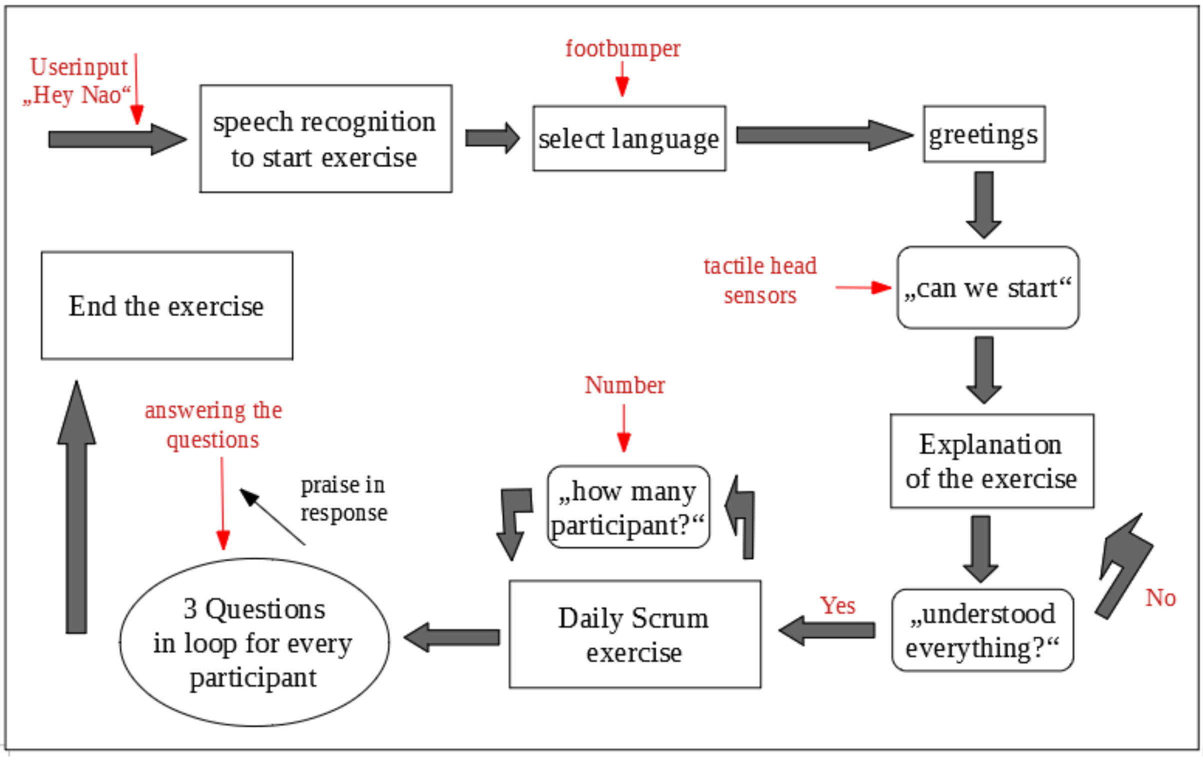
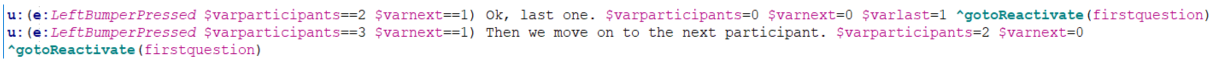


Figure 1. The diagram of the daily scrum with the NAO robot.

The daily scrum exercise starts with the user audio input “Hey NAO”. The NAO robot recognises the utterance and greets the user. After that NAO starts the exercise. First, NAO asks whether the exercise should be conducted in English or German. The language is selected using NAO’s foot bumpers. Then NAO gives a brief overview of what will happen in the exercise and asks if all participants are ready. After tapping NAO’s head, which the robot registers with the help of its sensors, the actual exercise starts. In general, as the exercise progresses, NAO asks if all participants are ready. This means that participants always have breaks that can be used to clarify questions or that the students can take notes. After explaining the exercise and asking whether everything was understood, NAO begins with the daily scrum. NAO asks the students how many participants besides itself take part in the exercise and then repeats the number of participants to make sure that it was understood correctly. Then NAO repeats the three questions of the daily scrum, as often as the number of participants. After answering the questions, NAO thanks participants for participating and ends the exercise.

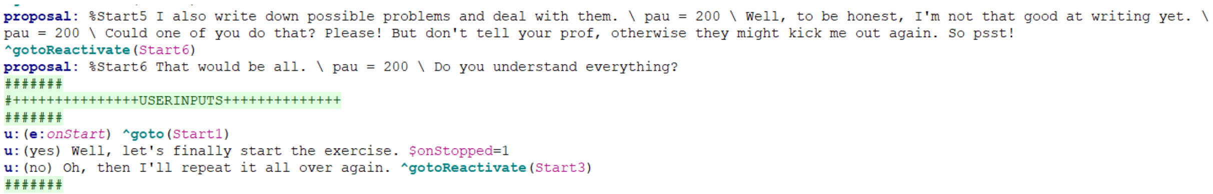
The daily scrum exercise was mainly implemented with the help of dialogues in Choregraphe in both German and English. During the course of the exercise, NAO asks the participants to press one of its foot bumper. This clear tactile feedback can easily be used in dialogues (see code example, Fig. 2). In addition, it offers clear advantages over the speech recognition limitations, since NAO does not perform reliably if the participant speaks too softly, is too far away from the robot or there are too many background noises in the room.



```
u:(e:LeftBumperPressed $varparticipants==2 $varnext==1) Ok, last one. $varparticipants=0 $varnext=0 $varlast=1 ^gotoReactivate(firstquestion)
u:(e:LeftBumperPressed $varparticipants==3 $varnext==1) Then we move on to the next participant. $varparticipants=2 $varnext=0
^gotoReactivate(firstquestion)
```

Figure 2. Code example for using NAO's tactile sensor of the left foot bumper.

Finally, another consideration when programming the NAO robot is its personality. Applying a humanoid robot rather than any other type of robot or computer for the daily scrum exercise followed the aim of simulating a human-like social interaction. Moreover, studies have shown that a humorous personality of a robot as an interaction partner tends to stimulate empathy [11]. The study by [11] applied dialogues with NAO which included query dialogues for providing knowledge and the phatic dialogues for casual responses (small talk) with personality effect. The study showed that the participants laughed more as response to the phatic dialogue compared to the query dialogue [11]. In order to achieve the best possible user experience during the daily scrum exercise, it was important to give NAO a unique personality. The aim was to evoke the feeling that the robot is having a realistic and personal conversation with the participants. The dialogue below shows an example of a phatic response programmed for NAO to convey a humorous personality (Fig. 3).



```
proposal: %Start5 I also write down possible problems and deal with them. \ pau = 200 \ Well, to be honest, I'm not that good at writing yet. \
pau = 200 \ Could one of you do that? Please! But don't tell your prof, otherwise they might kick me out again. So psst!
^gotoReactivate(Start6)
proposal: %Start6 That would be all. \ pau = 200 \ Do you understand everything?
#######
#+++++++++++++++USERINPUTS++++++++++++++
#######
u:(e:onStart) ^goto(Start1)
u:(yes) Well, let's finally start the exercise. $onStopped=1
u:(no) Oh, then I'll repeat it all over again. ^gotoReactivate(Start3)
#######
```

Figure 3. Example dialogue with a phatic response from the NAO robot.

The daily scrum exercise was pre-tested twice before the actual application during the class in the APM course. Two students from the humanoid robotics program took part in the first pre-test. These students provided the developer with the important information on how to improve the interaction between the user and the NAO. Two students who previously had no contact with robots took part in the second pre-test and provided further valuable suggestions for improvement. After the two pre-tests, NAO interactions were specified and some parts of the dialogues were modified.

2.3 Research instruments

The key research question for this study was: *How do students perceive a humanoid robot as an educational technology and how do they assess the interaction with a humanoid robot in hybrid learning settings?* In order to collect the data to answer this research question, an online survey was designed using a range of items, including items from a validated psychometric scale HRIES.

The perceptions of the interaction with the NAO robot were assessed using items from the Human-Robot Interaction Evaluation Scale (HRIES) proposed by [12]. The Human–Robot Interaction Evaluation Scale (HRIES) is a composite questionnaire used to evaluate how humans perceive robots and attribute human characteristics to them [12]. The scale is based on a taxonomy linked to recent findings in psychology and neuropsychology of Human Robot Interaction (HRI) and includes four sub-scales, i. e. Sociability, Agency, Animacy, and Disturbance. Each sub-scale includes a set of four semantic items describing characteristics of a robot. These items are used as stimuli and evaluated on a scale from 1 "not at all" to 7 "totally". The Sociability sub-scale includes four semantic items: warm, trustworthy, friendly and likeable. This sociability construct is positively related to the intent of interaction with others [12]. The Agency sub-scale includes the items: rational, self-reliant, intelligent and intentional, and is a measure of the capacity of a robot to act positively or negatively as an anthropomorphic agent [12]. The Animacy sub-scale includes the items: human-like, real, alive and natural. This construct is related to human characteristics of non-human agents and is linked to the concepts of “living” and “humanization” [12]. Finally, the Disturbance sub-scale includes the items: scary, creepy, weird and uncanny. The disturbance construct is related to negative perceptions of a robot [12]. The reliability and validity of the HRIES scale were evaluated and confirmed in four different types of user studies [12].

Further students’ perceptions of the NAO robot were captured using a number of self-designed statements and questions about the interaction with the robot, similar to items used by [15], such as “Please describe your general impression of the robot”. The results from the online survey administered during the daily scrum exercise with the NAO robot are described in the section below.

3 RESULTS

3.1 Study sample

From the cohort of 40 students participating in the daily scrum exercise with the NAO robot, 27 responded to the online survey, which makes a response rate of 67.5%. 15 students participated in the experiment on the campus, and 25 students participated online via Zoom. Among the students who answered the online survey 13 participated on campus (48.1%) and 14 online (51.9%). All students in the study sample were undergraduate students participating in the course on Agile Project Management (APM) in the third semester of their studies in the bachelor program Digital Business (B. Sc.) at Berlin University of Applied Sciences in Germany. Most participants had no previous experience in interaction with a humanoid robot (81.5%). Most participants were 20 to 24 years old (48.1%), followed by students in the age group of 25 to 29 (29.6%). 15 students were male (55.6%) and 12 students were female (44.4%).

3.2 Human-Robot Interaction Evaluation Scale (HRIES)

The perception of the interaction with the NAO robot was measured with the Human-Robot Interaction Evaluation Scale (HRIES) described above. The results are summarised in the table below (Tab. 1).

Table 1. Mean values (M) and standard deviation (SD) for the four sub-scales of the Human-Robot Interaction Evaluation Scale (HRIES), 1 = not at all; 7 = totally.

Sociability	***Agency***	***Animacy***	***Disturbance***
warm M = 4.00 SD = 1.45	rational M = 4.83 SD = 1.11	human-like M = 3.74 SD = 1.25	scary M = 2.31 SD = 0.63
trustworthy M = 4.23 SD = 1.57	self-reliant M = 3.68 SD = 1.20	real M = 3.61 SD = 1.23	creepy M = 2.72 SD = 1.22
friendly M = 5.00 SD = 1.04	intelligent M = 3.82 SD = 1.44	alive M = 4.58 SD = 1.32	weird M = 2.87 SD = 0.99
likeable M = 4.87 SD = 1.06	intentional M = 3.95 SD = 1.28	natural M = 3.60 SD = 1.38	uncanny M = 2.67 SD = 1.07
total subscale M = 3.88	total subscale M = 4.52	total subscale M = 4.07	total subscale M = 2.65

The results summarised in the table above show that there was a low standard deviation (SD) across all semantic items, which means that students who participated in the study assessed the NAO robot in a very similar way, possibly independent of whether they participated in the experiment on the campus or online. The lowest SD values were reached for “scary” and “weird” in the disturbance sub-scale, which means that students assessed these attributes in a uniform way and did not perceive NAO as a negative agent (M=2.65). The highest mean values were reached in the agency sub-scale (M=4.52), which means that students perceived the NAO robot as an anthropomorphic agent who is able to respond either in a positive or a negative way. It is also interesting to notice, that the highest value in the agency sub-scale was reached for semantic item “rational” (M=4,83), which means that students perceived the NAO robot as a rational agent whose behaviour is based on the reasons for action. This is also supported by the high value for the semantic item “alive” (M=4.58). In fact, high values were also researched for the entire animacy sub-scale (M =4.07), which means that students perceived NAO as a living agent with human-like traits such as having their own thoughts and intentions. The semantic item with the highest value was “friendly” (M=5.00), which can be considered as a social trait of the robot and can imply that students positively assessed the pro-social characteristics of NAO [12]. Also other items in the sociability sub-scale, such as likeable (M=4.87), trustworthy (M=4.23) and warm (M=4.00) indicate that this positive evaluation of social characteristics of the humanoid robot may be related to the general acceptance of HRI and a positive evaluation of the capability of the NAO robot to socially interact with humans [12].

3.3 Students’ perceptions of the NAO robot

Further students’ perceptions of the NAO robot were captured using seven self-designed statements which were assessed by students on a scale from 1 to 7. The results are summarised below (Tab. 2).

Table 2. Mean values (M) and standard deviation (SD) for self-designed items related to students’ perceptions of the interaction with NAO, 1 = disagree strongly; 7 = agree strongly.

	M	*SD*
1. The interaction with NAO was interesting.	5.22	1.74
2. The interaction with NAO was exciting.	5.00	1.57
3. The interaction with NAO was motivating.	3.81	1.42
4. The interaction with NAO was frustrating.	4.93	1.41
5. The interaction with NAO was disappointing.	4.11	1.65
6. The interaction with NAO was helpful to understand how robots function.	4.44	1.76
7. The interaction with NAO was helpful to understand Daily Scrum.	3.59	1.80

The results summarised in the table above show that the highest mean values were reached for items 1 (M=5.12) and 2 (M=5.00), followed by item 6 (M=4.44), which indicates that students perceived the interaction with the NAO robot as interesting, exciting and helpful to understand how robots function. High mean values for negatively worded items (item 4 and 5) show that students did not perceive the interaction with the NAO robot as either frustrating or disappointing, which is an interesting finding, given the fact that NAO was not responsive during the first run and had to be restarted. The lowest mean values were researched for items 3 (M=3.81) and 7 (M=3.59), but even these values can be considered as positive, given the fact that over half of participants (51.9%) took part remotely in Zoom and were able only to observe but not interact with the robot.

The results also reveal higher values for the standard deviation (SD) across all items compared to the HRIES results described in Table 1. It was hypothesised that the type of participation, i. e. students who participated in the study on the campus or online, may be related to the differences in the perception of the robot. This hypothesis was tested using the t-test for independent samples with the significance level α = 0.05 to determine whether the means of these two groups are significantly different. The results of the t-test have shown that indeed there was a significant difference in means of the two groups but only for the last item “The interaction with NAO was helpful to understand Daily Scrum” (t = -2.391, p = 0.025). The box plots show that students who participated on the campus rated this item much higher compared to the students who participated online in Zoom. This is a plausible result, given the fact that students who participated online could only observe the exercise. This result also shows that active, physical interaction with the robot makes a difference as far as learning outcomes are concerned compared to a passive, virtual participation.

In addition, the online survey asked students to describe a general impression of the NAO robot, similar to the item used by [13], i. e. “Please describe your general impression of the robot”. Some positive comments included: “Very interesting”; “Nice to see that a robot can interact in that way”; “Looks cool!”; “sweet”; “It's cute”; “It looks very interesting, I want to play with it”; “Even if not everything worked perfectly, the robot was able to understand a lot”; “I really liked the movements of the robot"; “I am very impressed by the robot and his functions”; “The robot looks really good. Sometimes he takes a bit long to process information that he received but in general he works well!”; “He has a very cute optic and understands simple interaction”; “I am really impressed and it is nice to see what the future may look like”. Some negative comments ranged from: “Very cute but with little problems.”; “not smooth, a lot of problems”; “it is cute but a little dysfunctional”; “It was interesting, but I think it still needs some improvement”; “His performance was better in the pre-test. A room full of people was a bit too much for NAO”; “In principle, I saw in the introductory video that NAO works excellently (maybe too much micros?). Why he was so shy today unfortunately only the programmer knows ;-)"; “Didn't work as it should. Really bad performance!”; “not worth the money”. Furthermore, the survey asked the question “Do you think the NAO robot has a gender?”. Most students (59.3%) replied that NAO had no gender, while 14.8% thought it was male and 11.1% thought it was female.

Another set of five items was used in the survey to learn about the improvements that students would wish to see in the programming of the NAO robot. Students were provided with a list of issues that were identified during the pre-tests and assessed how important it would be to improve these issues on a scale from 1 = unimportant to 7 = very important. The results are summarised below (Tab. 3).

Table 3. Mean values (M) and standard deviation (SD) for items related to students' perceptions of the necessary improvements to the programming of the NAO, 1 = unimportant; 7 = very important.

	M	*SD*
1. Speech recognition	5.00	1.26
2. Delay problems (latency)	4.69	1.54
3. Smooth movement	3.39	1.27
4. Dialogue with humans	4.95	1.27
5. Matching of speech and movement	3.30	1.36

The results summarised in the table above show that there was a low standard deviation (SD) across all items, which means that students who participated in the study assessed the necessary improvements to the programming of the NAO robot in a very similar way, possibly independent of whether they participated in the experiment on the campus or online. Students considered speech recognition (M=5.00), dialogue with humans (M=4.95) and delay problems (M=4.69) as the most necessary improvements to NAO. As already pointed out by [10], the built-in microphones in the NAO robot are not very reliable due to noisy motors, and need intensive preprocessing to allow for speech recognition. Therefore new solutions will be aimed for in future application scenarios of the NAO robot with students in higher education.

4 CONCLUSIONS

In order to improve the understanding of human-robot interaction (HRI), it is important to explore the interaction of different robots with diverse groups of users. This paper contributes to this field of research by describing an application scenario of the NAO robot integrated into the curriculum in higher education and providing results from a study focused on perceptions of students in higher education related to interaction with the humanoid robot NAO applied as an educational technology to facilitate a daily scrum meeting as Scrum Master with small teams of students . The study presented in this paper shows that higher education students, similar to other user groups, such as younger school children, perceive the humanoid robot NAO as a friendly, likeable, funny and trustworthy anthropomorphic agent. These results are in line with other studies with the NAO robot in the context of higher education such as [4] and [6].

The results of this study also indicate that humanoid robots such as NAO may be helpful for enhancing the engagement of students in higher education, since even older students perceive the interaction with the NAO robot as interesting and exciting. Based on the insights from the study presented in this paper, the key suggestions for further uses of humanoid robots in higher education include the use of robots such as NAO for short and simple engaging activities integrated into curricula, which can help attract students' attention to selected topics or enhance selected competencies. Such humanoid robot-led activities can be designed for short and entertaining breaks during regular or hybrid classes The application of robot assisted learning can be also used to enhance the understanding of students about how (humanoid) robots work, how they are programmed and what their current technical limitations are. Furthermore, robot supported collaborative learning can be used to enhance interaction and collaboration in student groups [6].

The recommendations for further research in the field of humanoid robot assisted learning include further exploration of student-robot interaction, especially in repeated application of a robot as opposed to one-time application, in order to understand the long-lasting potential of applying humanoid robots in education [6]. Further research should also include the design of new HRI research instruments based on existing scales such as HRIES [12] and the Godspeed questionnaire [6] to investigate human robot interaction in more depth and from diverse perspectives, e. g. students from different backgrounds and with different sets of digital competencies. As already indicated by [12], the improvement of current theoretical constructs and research tools is necessary to better understand and to design human-robot interactions, including the applications of existing and production of future humanoid robots for their use in (higher) education.

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